Intelligent Hybrid Thermo-Chemical District Networks

Philipp Geyer, Prof. Dr.-Ing., KU Leuven (Coordinator)
Muhannad Delwati, MSc., KU Leuven
Christian Engel, Dr.-Ing., Thermaflex
Martin Buchholz, Dr.-Ing., Watergy GmbH
Andrew Smallbone, PhD, University of Newcastle

Smart Energy Systems and 4th Generation District Heating
12 September 2017 · Copenhagen

Co-funded by the Horizon 2020 programme of the European Union, Grant No. 695780
Thermo-chemical processes

Humid air

Water

Condensation

680 kWh/t

Humid air

Thermo-chemical Fluid (TCF)

Absorption

680 kWh/t

Released humidity

Thermo-chemical Fluid (TCF)

Desorption / Regeneration

Provide three services in a thermo-chemical network:

«use case»
Industrial drying

«use case»
Space heating

«use case»
Space cooling

Provide three services in a thermo-chemical network:
Industrial drying

• Absorption produces dry air
• Usable directly for drying
  – Reduction of primary energy consumption
• Humidity control by stabilization function of TCF
Heating and heat recovery

External humid air sources (Greenhouse as building-attached Humid air solar collector)

Internal sources: Heat recovery (sensible/latent)

Concentrated TCF

Absorber

Diluted TCF

Heating demand

«use case» Space heating

Heating and humidity control service

Absorber

Space heating
Space cooling

Hot outside air → Concentrated TCF → Absorber → Diluted TCF → Heat rejection → Evaporator

«use case» Space cooling
Regeneration on supply-side

Heat Source/factory

Low-temperature excess heat (30..60°C)

Desorber

Concentrated TCF

Diluted TCF

Environment

- Concentrated TCF

- Regeneration on supply-side

- Low-temperature excess heat (30..60°C)
Thermo-chemical processes in a network

Desorption on supply-side

Dried warm air

Desorber

0.75 m³ Concentrated TCF

Diluted TCF 1 m³

Vapor 0.25 m³

Transport and storage in the network

Absorption on demand-side

Vapor 0.25 m³

Concentrated TCF 0.75 m³

Released heat 170 KWh

Absorber

Diluted TCF 1 m³

Dried warm air
Plan for CO₂ reduction • Local employment

Community

H-DisNet solution designer

H-DisNet

Energy Provider

Users with residual heat

Higher efficiency; low heat price “green points”; humidity control

Cost of energy; CO₂ emission trading; prevention of humidity damage; green labelling

Combustion free technology; develop “green” jobs Demonstrator 10-15 buildings

Users with high-humidity

Building Owners/Investors

ROI <5-10 years • Higher value of building • Protection of building against humidity damages

Demonstrator

Use case 2: Humidity setpoint control

Use case 1: Humidity removal / Drying

Use case 4: Space cooling

«use case»

«use case»

«use case»

Building services

Humidity control combined with heating and cooling • Better indoor climate creates value • Investments often are not dividable among tenants

Compliance to local regulations; Proof of solution

Performance guarantee; Deadlines / budget; Maintenance

Integrator (installer, subcontractor)
Use case 3: Space heating

UC 3.1: Heat recovery
- Sensible and latent heat recovery
  - Air ventilation system
  - Limited heat demand (estimated < 50 kWh/m²a)

UC 3.2: Provide heat for spaces
- Heat pump functionality
  - Temperature lift: 10..20K

Volume: high, 11,724PJ/a in the EU

TCF application conditions for heating
- Air heating: 15/25°C, 85..95% lifted to 35°C, <30%
- Sensible and latent heat recovery: 19..25°C at 30..70%

Feasibility: easy / medium difficult

Heat pump (pure electric or PV-T)

Fossil fuel heating systems (gas, oil)
Transport and storage in the network

TCF supply
Network pipes

TCF: LiCl-H$_2$O
$T_{\text{f\_in}} = 14^\circ\text{C}$
$m'_{\text{f\_in}} = 0.1..5 \text{ kg/s}$
$C\%_{\text{f\_in}} = 35\%$

Transport and storage in the network

Heat Exchanger

External humid air sources
(building-attached greenhouse, façade collector)

$T_{\text{a\_in}} = 20^\circ\text{C}$
$Rh_{\text{a\_in}} = 80\%$
$m'_{\text{a\_in}} = 1..6 \text{ kg/s}$

Absorber

Concentrated TCF

Diluted TCF

TCF return
Network pipes

TCF: LiCl-H$_2$O
$T_{\text{f\_out}} = 20..30^\circ\text{C}$
$m'_{\text{f\_out}} = 0.1..5 \text{ kg/s}$
$C\%_{\text{f\_out}} = 22..30\%$

Building
$V = 1000 \text{ m}^3$
$T_{\text{in\_Design}} = 22^\circ\text{C}$
$T_{\text{out\_Design}} = -8^\circ\text{C}$
Heat losses = 12.8 kW
$T_{\text{outdoor}} = \text{cont} = 5^\circ\text{C}$
Heating and heat recovery
Modelica Simulation Model
Heating and heat recovery
Simulation results

Temperature vs airflow and TCF flow

Heating power vs airflow and TCF flow
Conclusions

• Three services: Heating, Cooling, Drying
• Return-flow exploitation
  – Extending network capacities
  – Interesting new service: Drying/Humidity control
• Heating has been shown in simulation
  – Low-temperature
  – High air recirculation

Future work:
• More realistic simulation
• Switch from physical multi-node simulation to quick-responding substitute model (machine learning) for simulation and control
• System-level validation of models at demonstrators
• Case studies on networks examining economic and environmental performance